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RESEARCH ON THE TRANSPORTATION OF SOLIDS BY PIPELINE IN FRANCE

by

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RESEARCH ON THE TRANSPORTATION OF SOLIDS BY PIPELINE IN FRANCE

by

R.P. Charbonnier*

INTRODUCTION

The transportation of solids in pipelines is presently under serious consideration in Canada, as a possible improvement of the usual shipment methods for various bulk materials, with a view to reducing the high shipping costs now charged by the railways for coal, ores, sulphur, etc.

During a field trip by R.P. Charbonnier in Europe in Summer 1962, enquiries were made from numerous organizations to ascertain the importance of the research activities and facilities, available in the field of solids pipelines. Outside of the USA and Canada, most of this type of research seems to have been carried out in Great Britain, France, and communist countries. In Britain, an abundant documentation was collected, and detailed discussions were held with officials of the National Coal Board, (NCB), the Central Electricity Generating Board (CEGB), and many other organizations. Later, a visit was made to the CEGB solids pipeline research station in Brighton-Hove. The extensive information thus obtained was reported in detail in Report IR FMP 62/166-PRE, entitled "Working Party on Movement of Solids, Report No. 4, Research on the transportation of solids by pipeline in Britain" by R.P. Charbonnier (September 1962). After a brief note on the German coal pipeline project, the present report describes solids pipeline research in France.

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COAL PIPELINE IN GERMANY

In Western Germany, there is a large project now under study, for the hydraulic transportation of coal in a pipeline of 40 cm of diameter, on a distance of about 200 miles southward from the Ruhr area. This project, which will be a costly one, is being handled by a financial group consisting of the Ruhr Coal Advisory Company, the Society for Hydraulic Transportation, and the Hard Coal Mining Association (Steinkohlenbergbauverein, Dr. Reerink, Mr. Grimm, Mr. Lemke, Mr. Puff of Ruhrgas AG). From personal contacts, in Essen and at the University of Stuttgart, it appears that most of the technical research conducted in Essen for this project has been primarily on the behaviour of coal in water in dependence on the upper particle size limit, the grain structure of the solid material, and the ratio of solid material to water. These studies have been carried out by the Steinkohlenbergbauverein Research Establishment in cooperation with the Ruhrgas AG. Regarding the coal pipeline installation, it seems that the flow-sheets and the cost estimates for the two terminal stations are now in the last stage of planning. The situation is similar for the alinement and the cost estimates of the pipeline itself. It is hoped that most of the technical studies to be done in Germany will be completed by the end of 1962. This coal pipeline is expected to have an annual capacity of the order of 3 million tons.

It appears that most of the specialized engineering research for this project is obtained from the Consolidation Coal Co., in the USA, acting as engineering consultants, on the strength of its experience in the building and operation of the 100 mile coal pipeline Cadiz-Cleveland (Ohio).

TRANSPORTATION OF SOLIDS BY PIPELINE IN FRANCE

Neyrpic-Sogreah Research Organization

As it was confirmed that the Neyrpic-Sogreah industrial group has been doing most of the research and engineering work in this field in France, a visit was made by R.P. Charbonnier to the research centre in Grenoble, France. Neyrpic is one of the largest hydraulic equipment manufacturers in the world, with experience going back to 1854. The Neyrpic group has more than 5,000 employees. The "Societe Grenobloise d'Etudes et d'Applications Hydrauliques" (SOGREAH) is the Neyrpic subsidiary, acting as consulting engineers, preparing special studies and conducting research work. Sogreah has

over 1,100 employees, including 320 graduate engineers and scientists, and 380 technicians. It has agencies in 70 different countries. The research centre in Grenoble includes vast hydraulics laboratories with large scale models of harbours, dams, hydraulic installations, etc, electronic computing facilities (IBM 7070 and 1401), a very comprehensive technical library and documentation service, including about 20,000 specialized books and 800 periodicals, testing installations for hydraulic machines, and industrial installations on a pilot plant scale, and also a soil analysis laboratory. In applied industrial hydraulic research, a section is devoted to the hydraulic sorting and handling of materials, including the conveying, separation and grading of solids in fluids, and the designing and setting up of installations for the pipeline conveying of coal, cement, slurry, ores, sand, gravel, phosphates, slag, pulp, manufactured products, etc. Another section deals with hydro-mechanical research and hydraulic machinery testing (pumps, valves, etc.). Detailed economic and financial studies are also carried out at this large research centre. It may be noted that another section deals with the pneumatic conveying of solids (usually on short distances), and therefore research facilities regarding both techniques (pneumatic and liquid pipelines) are available from the same organization, which is also working in cooperation with the University of Grenoble, of world-wide reputation.

Sogreah Solids Pipeline Research Station

Discussions on the available facilities and past achievements in this field were held with Mr. Paul Gariel, Mr. E. Condolios, and some of their colleagues. An abundant documentation was collected, including a detailed report entitled "Les activites de SOGREAH dans le domaine du transport hydraulique des materiaux en conduite", Rapport SOGREAH, DAI-TMH, N.T. 1028, 1962. This voluminous report describes the activities of SOGREAH in the hydraulic transportation of materials in pipelines, with numerous photographs of various aspects of their research installations for solids pipelining, and a list of solids pipeline projects studied up to date.

The loops of test pipes available have lengths, that can be adjusted according to the particular test requirements, up to 350 meters, although most tests involve shorter lengths between 20 and 100 meters, with a few tests on 200 m lengths. The various loops of pipeline include full circuits of pipe, having 40 mm, 100 mm, 150 mm and 250 mm in diameter (i.e. about 1.6 inch, 4 inch, 6 inch, and 10 inch diameters). On all these sizes, tests can be conducted on horizontal, vertical, and inclined sections, as well as on various elbows. The experimental pipelines are equipped for the sampling of the mixed solids and fluids, and for observations, photographs and moves through transparent plexiglass pipe sections. The various pumps are driven by gas engines, Diesel and electric motors from 30 to 130 KW at variable speeds. The

pumps (e.g. Bergeron SN. 75 units) have capacities from 20 to 500 cubic meters/ hour, and can transport up to 150 tons/ hour of solids. Centrifugal and piston pumps are used, sometimes in series of 2 or more pumps. Velocities up to 10 m/ s have been obtained. Some tests are to be undertaken in copper pipes of 100, 150 and 200 mm of diameter.

Among the materials tested for pipeline transportation since the large scale installation started operations in 1947, the following are most notable: bauxite tailings, limestone, radioactive capsules, coal (sized and fines), iron ore, slag, pulp, cement paste, phosphate, agglomerated powders, sand, gravel, ash, and salt.

For the introduction of solids in the pipelines, lock hopper feeders are available. There are also two installations for the evaluation of pipeline wear caused by the abrasive characteristics of each solid to be transported. Both impact wear and friction wear can be assessed by standardized tests. Pump wear can also be tested on special pumps. Some tests have been made with pipe of 800 mm, i.e. about 32 inch, of diameter. However with the wealth of data now collected after numerous tests on a variety of materials, it is felt that the tests on large pipes are generally no longer necessary, and that they take too much time to set up. The tests on smaller pipe are quite sufficient, faster, and much cheaper.

The first solids pipeline test loop, installed in 1947, had a pipe diameter of 250 mm and was 500 meters long, with 50 m inclined sections. The pump could deliver 350 cu. m./ hr at 3 kg/ cm^2. The second test loop, in 1949, used a pipe of 100 mm diameter and was 200 m long. The third installation, built in 1950, includes 4 test loops of 40 mm diameter, with 2 transparent sections of 25 m length, and vertical sections of 6 m. height, which can be inclined at any angle. Centrifuge pumps with variable speed (1 to 6) can give velocities between 0.2 and 10 m/ second. Another test loop was installed on a distance of 120 meters, with sections of 100 mm and 150 mm diameters. Transportation time to complete the circuits of these loops is 40 seconds to 1 minute. In order to avoid excessive size degradation due to the numerous passages in the pumps, etc., semi-open circuits are often used with intermediary storage bins. For instance, about 10 tons of solids may be used to study the transportation characteristics in a loop containing only a maximum of half a ton of solids at any time. Two other loops of 200 m length were built with pipes of 150 and 250 mm diameter. A centrifugal pump driven by a 130 HP Diesel engine can move up to 400 m^3/ h at 5 kg/ cm^2 (the pump speed varying in a 1 to 5 ratio). A 12 m long section of 150 mm pipe can be inclined between 0 and 90 degrees.

A special test loop for studies on paper wood-pulp is entirely made of transparent plexiglass pipe of 50 mm diameter, and 40 meters in length. It will be supplemented next year by a loop of 80 or 100 mm diameter pipe. These tests have been used in connection with the building of plant pipelines about 1000 m long for the transportation of pulp at high speed (up to 10 m/ sec) and very high concentrations. Then the observed phenomena are more closely related to fibre mechanics than to hydraulics.

Special wear tests have been conducted with piston pumps on 50 m long loops of 50 mm diameter pipe, up to 15 kg/ cm^2.

As an alternative to lock hopper feeders, injectors for relatively coarse solids have been tested and found suitable especially for the smaller installations.

Achievements of the Neyrpic-Sogreah Organization in the Transportation of Solids by Pipelines

Some detailed data have been obtained on the 44 most notable projects of solids pipelines, which have been studied by Sogreah, including a dozen projects, carried out to completion of the industrial construction of the installations. Following are brief notes on some of these projects, classified according to their nature.

A) Public Works and Dredging

Reference No. 2: Hydraulic transportation of various solids in pipelines (Model Study and full scale tests for the Public Works Department of Loire Atlantique, France). Experimental conditions varied as follows. Sizing: 0.3-0.4 mm, 0.7-1 mm, and 0.1-5 mm; transported solids: sand, ores, rubber, plastics; transportation with and without deposits, using various solids contents between 0 and 500 grams/ litre; tests in horizontal, inclined and vertical loops of 40-104-150 and 250 mm pipes. Operating curves were thereby established for optimum dredging, with transportation of solids over 200 to 2000 meters, in capacities of 100 to 1000 m^3/ hr, through pipelines of 580 and 700 mm of diameter.

Reference No. 4: Hydraulic transportation of solids in a dredge of type CNR II at Donzere (Model study and full scale tests for " Ateliers and Chantiers de Bretagne", France"). The 330 mm diameter pipeline of 400 m length had a capacity of 150 m^3/ h of 0-100 mm solids.

Reference No. 6: Hydraulic transportation of sands at Sete. (Model study for the Public Works Department of Herault, France). These tests were carried out on pipeline loops of 40 mm diameter. The full scale pipeline was built to transport 250,000 m^3/ year of sands over 3 to 5.5 km to fill the swamps of Ingril and Eaux Blanches.

Reference No. 18: Control of solids pipelines (Development of a patented recording instrument for the Public Weeks Department of Loire Atlantique, France). This recorder, showing the capacity and solids contents of a pipeline with instantaneous and integrated measurements of flow, pressure, volumes, and concentrations, was developed by Sogreah especially for sand pipelines of 700 mm diameter.

Reference No. 20: Hydraulic transportation of sands at the Benin harbour. (Model study for the Public Works Department of Dahomey, Africa). Determination of the characteristics, costs, and power required for a dredging pipeline with a capacity of 2 million m^3/ year.

Reference No. 21: Hydraulic dredging of sands at Grau St. Ange. (Model study for the Fisheries Committee of the Barcares Swamps, France). On the basis of the records of storms and physical conditions of the seashore, the characteristics of the required installation were established (for instance a capacity of 500 m^3/ day to transport the sands).

Reference No. 28: Hydraulic Transportation of sands from the Hoogly river to fill the Salt Lakes area. (Model study for "Inter-Invest Anstalt, Calcutta, India). This study determined the characteristics of the pumping stations and control systems of a 6 km pipeline to transport 18 millions of m^3 in 6 years.

Reference No. 33: Hydraulic transportation of sands at Bluff Harbour. (Model study for the "National Public Works Company", France). This project covered the determination of the characteristics of the pipelining of 1,000 m^3/ h of dredged sands over a distance of 1 km.

Reference No. 34: Pipelining of sands in the Dunkerque harbour. (Model study for "Societe Francaise de Dragage", France). Determination of the characteristics of the pipelining of 2,000 m^3/ h of dredged sands over a distance of 7 kms.

Reference No. 43: Pipelining of diamond-bearing gravels and tailings. (Model study and full scale construction for SAREMCI, Tortiya, Ivory Coast, Africa). The purpose of this 300 to 400 meters pipeline is to recover the diamonds from sedimentary gravels and old tailings (minus 40 mm in size).

B) Hydraulic Transport of Coal, Hydraulic Lift, Stowing.

Reference No. 1: Coal pipeline Merlebach - Carling (Model study for the National collieries of Lorraine, France). This was one of the first large scale projects undertaken by Neyrpic-Sogreah (1947). The tests were conducted on a pipeline loop of 300 m length in 250 mm diameter pipe. The pipeline was built to carry about 1 million tons of minus 2.5 mm coal per year from the Merlebach mine to the E. Huchet power plant (a distance of 9 km) in a pipe of 375 mm diameter. The maximum capacity is 360 tons/ day but the usual load is about 240 tons/ day, with a velocity of 1.6 m/ s.

Reference No. 3: Hydraulic transportation of mine rejects at the Couriot shaft. (Model study for the National Collieries of Loire, France). Determination of the characteristics of a pipeline to carry about 30 tons/ hr over a distance of 800 meters, with a 90 meters difference in altitude.

Reference No. 8: Pipeline for stowing with sandstone. (Model study for the National Collieries of Lorraine, France). These tests were carried out on a pipeline loop of 150 mm diameter to determine the characteristics of a pipeline system of mine stowing with sandstone in clayish muds. The distances involved were 300 to 500 meters vertically and several kms horizontally.

Reference No. 14: Coal pipeline for the mine of Havelock, South Africa. (Model study for Fraser and Chalmers). This pipeline should transport 30,000 tons/ year of minus 30 mm coal by gravity from the colliery to a power plant about 2 miles away. The study included the lock hopper feeder arrangements and also wear tests.

Reference No. 22: Pipeline transportation of coal washery rejects at Lievin. (Model study for the National Collieries of the North, France). This project included the determination of the characteristics of a pipeline to carry about 12 tons/ hr of flotation rejects in 100 to 200 m^3/ hr of washery water, with a concentration of 20 to 100 grams/ litre, over a distance of 1150 m, up to a height of 23 m.

Reference No. 32: Hydraulic transportation of coal in the Devillaine shaft, St. Etienne. (Model study and full scale construction for CERCHAR and the National Collieries of Loire, France). This pipeline was built to lift about 50 tons/ hr of minus 80 mm coal and shales from the mine shaft bottom at 145 m below the surface to a height of 33 m above the surface in the coal washery. The Sogreah ES 450 centrifugal pump has a capacity of 210 m^3/ hr, giving peaks of 60 tons/ hr of solid materials from a vertical lock hopper feeder. The pipeline has a diameter of 200 mm and uses a closed water circuit.

Reference No. 38: Hydraulic lift and horizontal transport of ore. (Model study for White Pine Copper Company, USA). This feasibility study of a copper ore pipeline dealt with three possible solutions depending on where the ore crushing and grinding would be done: at the flotation plant, at the top of the mine shaft or at its bottom. The required capacity of this pipeline is 5 million tons/ year (about 5, 500 t/ shift) of minus 100 mm raw ore or minus 0. 05 mm crushed ore, of 2. 5 to 2. 85 density. The pipeline length is 765 m vertically and 2. 7 km horizontally.

C) Hydraulic transportation of various materials

Reference No. 10: Hipeline for manganese ores (Model study for Franceville, Gabon). Determination of the characteristics of two pipeline projects for the transportation of 500, 000 and one million tons/ year of manganese ores from the Franceville area to the Pointe Noire railroad line over a distance of 350 kms.

Reference No. 15: Pipelines for agglomerated powder (Model study and full scale construction for "Direction des Poudres", Bergerac, France). Ten pipeline circuits have been built in lengths from 60 to 240 m to transport about 600 kg/ h of gun powder sticks in about 25 m^3/ h of water. The gun powder sticks are cylindrical with lengths between 9 and 20 mm, and diameters from 4 to 7 mm.

Reference No. 16: Pipeline for the rejects from an asbestos mine at Olmeta. (Model study for the Pont a Mousson Co., Olmeta-Cap Corse, France). Feasibility study for a pipeline to transport 100 t/ h of minus 7 mm rejects from the asbestos plant to a deposit area under the sea at a distance of 1 km and a depth of 40 m.

Reference No. 17: Pipeline for the slag from electric ovens. (Model study and full scale construction for the "Le Nickel" Co., Doniambo, New Caledonia, 1958). The slag from four Elkem ovens are rejected in the sea over a distance of 200 m gradually extending to 600 meters. Each oven rejects 70 t/ h of slag at 1600°C every two hours. The slag is broken up into 8 to 50 mm particles by 500 m^3/ h of sea water, and the mixture of solids and sea water is transported to the sea through a pipeline of 200 mm of diameter. The maximum range for one pump is 300 m and for two pumps in series it is 600 meters. The power required is 125 HP for 300 meters. Since 1959, the four installations carry about 1.5 million t/ year.

Reference No. 19: Hydraulic transportation of phosphates. (Model study for "Phosphates du Benin", Togo, Africa). This project is a feasibility study for the pipeline transportation of about two million tons/ year of phosphates over a distance of 2.5 km.

Reference No. 25: Pipeline transport of uranium ore. (Model study and full scale construction for the "French Atomic Energy Commission", Division of Forez, France, 1959). This pipeline transports about 200,000 t/ year since 1959 from the preparation mill to the chemical plant (for the preparation of uranile nitrate). The capacity of the pipeline is 25 t/ h of dry ore, its length is 600 m, the outlet being 45 m higher than the inlet. The ore is a minus 500 microns ground quartz with 0.3% uranium plus clays. It is very abrasive. After grinding, the slurry is thickened from 200 gram/ litre to 720 g/ l. Two pumps are used in series (one with variable speed). The pumps and the 90 mm diameter pipeline are lined with rubber, which is quite satisfactory for wear, although some pump parts may be made in Ni-Hard eventually.

Reference No. 26: Hydraulic transportation of slag. (Model study for "Cimenteries de Rombas", France). This is a study of a pipeline to carry about 1,000 t/ day of minus 5 mm slag (density 2.1) from the Sidelor blast furnaces to the Rombas ciment plant. Two solutions were considered: either with a lock hopper feeder or with a solids handling pump.

Reference No. 27: Water pipeline for sulphur from Lacq to Bayonne. (Model study for the "Societe Nationale des Petroles d'Aquitaine, France). Two alternatives were studied for the hydraulic transportation of 4000 t/ day of sulphur from the gas field of Lacq to the Bayonne harbour over a distance of 85 kms: the transportation of sulphur pieces or the pipelining of a sulphur slurry. The latter solution, although requiring a grinding down to minus 50 microns, was preferable mainly because of its lower costs.

Reference No. 31: Hydraulic transportation of phosphates (Feasibility study and full scale construction for the "Compagnie Senegalaise des Phosphates de Taiba", Senegal, Africa, 1960). The Taiba phosphates are covered by a sand formation of 15 m thickness. The production of the phosphates is carried out by floating draglines, feeding 350 tons/ hour (about 2 million t/ year) of minus 3 mm phosphate into a pipeline, with 3 pumping stations over a distance of 2, 300 m to the phosphate preparation plant, located 30 m higher. The total power required is 900 HP.

Reference No. 35: Water pipelines for diamond bearing gravels. (Feasibility study and full scale construction for "SAREMCI", Tortiya, Ivory Coast, Africa). Several pipelines have been built to connect various sections of the preparation plant. For instance, a pipeline of 500 m length carried about 1 million tons/ year at a rate of 100 t/ h from the mining operations to the plant. Inside the plant, at various points the gravels are pumped into pipelines up to a height sufficient to permit gravity feeding to the preparation apparatus. Finally, the plant rejects are removed at the rate of 30 t/ h over a distance of 300 m.

Reference No. 36: Hydraulic transportation of salt. (Model study and full scale construction for "Kuhlmann", Brignoud, France). The carrier is salt water in the form of brine, which is recovered, since the pipeline forms a closed circuit. About 60 to 80 tons/ hour of minus 25 mm salt is carried up to a height of 7 m from the unloading pit to a storage area. Kuhlmann is a very large chemical company.

Reference No. 37: Pipeline for bauxite rejects to the sea. (Feasibility study for "Pechiney", Gardanne, France.) Pechiney is another very large chemical company, which has requested the study of a pipeline to carry away about 2, 500 m^3/ day of residual muds, from an alumina plant to a discharge point at about 1000 m of depth in the Mediterranean sea. The pipeline length will be about 50 kms, including 12 kms in the sea. The 250 mm diameter pipeline should carry about 1, 200 t/ day in 1963, and ultimately 3, 000 t/ day of minus 500 micron rejects.

Reference No. 41: Pipeline for mine and sewer refuse. (Feasibility study for the Shoshone County Commissioners, Idaho, USA). To prevent pollution in the Coeur d'Alene river valley, this pipeline would have to carry away the rejects of 8 mines, 3 chemical plants, and the city sewers, over a distance of 50 kms to a swamp area. The total length of the pipeline, including the trunk feeder lines, would be 80 kms. The mine rejects consist essentially of 250 t/ h of 0.1 mm sands having a density of 3. Both centrifugal and piston pumps have been considered, with a single pipeline network or two parallel networks.

Reference No. 7: Hydraulic transportation of clay. (Model study for "Ets. Poliet et Chausson", Gargenville, France). This pipeline would transport about 150,000 tons/ year at a rate of 520 t/ day in one 7 hour shift from an open pit to the Gargenville plant, over a distance of 5 kms.

Reference No. 13: Water pipeline for crushed limestone. (Model study for the Metropolitan Portland Cement Ltd., Australia). This pipeline would transport 450,000 tons/ year of crushed limestone from the Marulan quarry to the Maldon plant over a distance of 103 kms. About 50 t/ h of minus 200 microns limestone would be moved by piston pumps with a total requirement of 200 HP. The pipeline would first go up to a height of 150 m and in the second section it would come down 615 m lower than the inlet.

Reference No. 40: Hydrablic transportation of crushed limestone. (Model study for "Calcareos San Fernando", Chili). About 200,000 tons/ year would be moved through a 75 km pipeline from a quarry at an altitude of 1,800 m, down to a cement plant at an altitude of 340 m, on an average slope of 19.5%. Two types of limestone must be transported: about 168,000 t/ year of crushed limestone for the cement plant, and 30,000 t/ year of coasse limestone for agriculture requirements. Both these amounts are expected to be doubled in a second period of operations. This study includes all the aspects of the pipeline project, and also the possibility of using a plastic pipeline rather than a steel pipeline, with all the ancillary facilities thus required (pressure control, surge and storage installations, etc.)

Reference No. 29: Pipeline transportation of iron ore. (Model study for the "Bureau Minier de la France d'Outre-Mer", Tchibanga, Gabon, Africa). This pipeline is to transport either 4 million tons/ year of minerun ores or 2 million t/ year of concentrates with a density of 3.7 over a distance of either 45.7 or 90 kms (difference in altitudes: 300 m). This study has included tests on a 40 mm diameter pipeline loop and also on a full size loop, as well as wear tests and economic analysis.

Reference No. 11: Hydraulic transportation of ashes and clinkers. (Model study and full scale construction for "Electricite de France", Thermal equipment area No. 1, France). Tests on pipeline loops of 40 mm, 104 mm, and 150 mm pipe diameter have been used to determine the optimum characteristics of pipelines for the transportation of ash, soot, and clinkers in suspension in water, at the rates of 32 tons/ hour over 1 km and 26 t/ h over 6 kms, from the thermal power stations of Porcheville and Vainville to reject disposal areas.

Reference No. 12: Hydraulic transportation of ashes at Kincardine, U.K. (Model study and full scale construction for Kennedy and Donkin, England, 1958). This study includes tests of the lock hopper feeders required and trials on pipeline loops of 40 and 150 mm diameter with solids concentrations from 110 to 380 grams/ litre. Finally the pipeline was built, with a diameter of 254 mm over a distance of 5 kms, to transport about 100 tons/ hour of minus 50 mm soot, ashes and clinkers in a flow of 62,000 gallons/ hour. The total power required for the operations is 120 HP. Eventually this pipeline is expected to move 240 t/ h.

Reference No. 39: Pipeline for soot and clinkers in Scotland. (Model study for the South of Scotland Electricity Board, U.K.) This project consisted of the size classification at 1 mm of the crushed soot and clinkers from the Cockensie thermal power station, in Scotland. This classification is obtained by Lavodune (Neyrpic-Sogreah) equipment. The plus 1 mm is transported by trucks, and the minus 1 mm in suspension in sea water is moved through a pipeline over 6 kms and rejected in the sea at a rate of 200 tons of solids per hour.

Reference No. 23: Hydraulic transportation of radioactive capsules. (Model study and full scale construction for the French Atomic Energy Commission and Saint-Gobain Co., Marcoule, France). The capsule pipelines transport radioactive containers from the exits of the Marcoule nuclear reactors over a distance of 120 m. The capsules have a length of 1.3 m and weigh from 14 to 18 kg. They are introduced into the pipelines by lock hopper feeders. Special facilities were built for the retardation and storage of the capsules at the outlets. Four pipelines are used with a rate of transportation of 20 capsules/ hour each.

Reference No. 24: Hydraulic pipelines for radioactive capsules. (Model study and full scale construction for the French Atomic Energy Commission, and "Electricite de France" EDF No. 1, Chinon, France). These two pipelines were built on the same principles as the four pipelines of Reference No. 23, but special model tests were necessary because of differences in the capsule characteristics. The containers at Chinon weigh about 19 kg and have a length of 1.25 m.. They are transported at the rate of 30 capsules/ hour over a distance of 160 m.

Reference No. 42: Hydraulic transportation of radioactive containers. (Model study for the French Atomic Energy Commission, Brennilis, France). Similar to References No. 23 and 24, this project deals with capsule pipelines for the EL 4 nuclear power station. Special problems are caused by the high speeds required for the heavy capsules (about 20 kg each with a density of 7).

Reference No. 44: Pipeline transportation of paper pulps. (Model study for the technical research centre of the paper, cardboard and cellulose industries, France). A special pipeline loop has been built for this project, since the motion phenomena are quite different for fibres and for the usual hydraulic suspensions.

Sogreah publications

Some publications by Sogreah scientists and technologists have been outstanding contributions to the literature on the hydraulic transportation of solids, notably the data and equations presented by R. Durand and E. Condolios. This contribution has been very useful to most of the other research workers in this field, and has generally been adopted as one of the theoretical basis of solids pipeline calculations.

The following publications are of special interest:

(1) Durand, R., and Condolios, E. "Etude experimentale du refoulement des materiaux en conduite". 2 emes Journees de l'Hydraulique, S.H.F., Grenoble, June 1952.

(2) Durand, R., and Condolios, E. "The hydraulic transport of coal and solid materials in pipes". Proceedings of a colloquium on the hydraulic transport of coal, held by the National Coal Board in London, on Nov. 5th and 6th, 1952, p. 39-52 — Also, Minneapolis congress of the "Association Internationale de Recherches Hydrauliques", 1953.

(3) Durand, R., and Condolios, E. "Donnees techniques sur le refoulement hydraulique des materiaux solides en conduite". Revue de l'Industrie Minerale, No. Special IF, June 1956, Paper 22 F, p. 459-81. Also English translation, Neyrpic Lab. R Du/ GJo/ MNF -14.4, 1955: "Technical information about the transportation of solids in pipes".

(4) Condolios, E., Couratin, P., and Pariset, E. "Transportation of Solids in Conduits, Industrial Application Possibilities". Engineering Journal, June 1961, 6 pp.

(5) Chapus, E., Condolios, E., and Couratin, P. "Hydraulic Hoisting of Coal and Ores". Mining Congress Journal, September 1962, p. 46-9.

CHARBONNAGES DE FRANCE — CERCHAR

The French National Collieries "Charbonnages de France" and their research organization "Centre d'etudes et recherche des Charbonnages de France — CERCHAR" have been active in the field of solids pipeline transportation for many years, especially regarding pneumatic and hydraulic stowing in mines, but also for coal transportation.

Discussions were held by R.P. Charbonnier with Mr. R. Coeuillet, Chief Engineer, and Mr. Tretiakow, at the French National Collieries, and Mr. P. Belugou, Chief, Department of Mining and Coal Preparation, Mr. P. Jacquemin, Chief, Programming Service, and Mr. J. Pechabrier, Chief, Documentation Service, at CERCHAR. An interesting documentation was thus obtained. The two main achievements in solids pipelining at the French Collieries have been the horizontal coal pipeline in Lorraine, and the mainly vertical pipeline in the Devillaine mine shaft.

Coal pipeline Merlebach - Carling

The first high capacity, long distance coal pipeline at least in the free world was planned in 1947, and has been in operation since 1952, between the Merlebach coal mine and the thermal power station Emile Huchet, at Carling, for the National Collieries of Lorraine, France. The E. Huchet power station was designed to use low grade residual products from coal washing. These intermediate middlings coals are obtained at Merlebach in the form of slurries of minus 3 mm coal in water, which are concentrated and pumped through a 175 mm diameter pipeline over a distance of 9.2 km to the Huchet plant. There the slurry is treated by centrifuges, filters and dryers. As noted above (reference No. 1) a model study of this pipeline was prepared in 1947 by the Neyrpic-Sogreah laboratories. The pipeline was built with a maximum capacity of 360 tons/ day, and was buried in the earth to avoid freezing hazards. The dangers of plugging the pipeline had been exaggerated, as shown when several interruption occurred with a full load of coal in the pipeline. Even after a fortnight, during which the fine coal had settled, the movement of coal was resumed without difficulty. The usual load is about 240 tons/ day, with a velocity of 1.6 m/ sec. It may be of interest to note that since 1960 all the coal transported by this pipeline is obtained from a section of the Freyming coal washery, consisting of 6 large Lavodune units of 425 mm of diameter. The Lavodune apparatus was designed and built by Neyrpic-Sogreah in cooperation with CERCHAR. Approximately 4 or 5 tons/ hour of shales, sands and pyrites, at 75% of ash content, are thereby eliminated from the pipeline coal feed, with an organic yield of 99%. These shales and sands would cause

excessive wear in the pipeline, and the pyrites would result in premature corrosion of the boilers. Finally, an interesting feature of this coal pipeline is that the amount of water necessary to transport the coal at the optimum concentration happened to be about equal to the quantity required for the condensers and auxiliary needs of the power station. The use of the pipeline water has therefore eliminated the expense of sinking the very deep water wells, that would have otherwise been required.

Coal pipeline at the Devillaine mine

This installation was designed and built by Sogreah-Neyrpic on the proposals of CERCHAR and the French National Collieries. It is essentially a vertical coal pipeline used to lift the coal from the bottom of the Devillaine No. 1 shaft, at the Loire Collieries, St-Etienne, France. It has been in operation since 1960. The closed circuit includes a clear water centrifugal pump, type Sogreah ES 450, with a capacity of 3.5 m^3/ minute under a pressure of 6 kg/ cm^2. This pump, driven by a 90 HP motor with variable speed, is located at the surface and pumps clarified water from the washery (average solids content: 140 grams/ litre) through a 200 mm diameter pipeline down the Devillaine mine shaft. At the bottom, the minus 80 mm unwashed coal is injected in the pipeline under a pressure of 20 kg/ cm^2 through a vertical lock hopper feeder with two compartments, designed by Sogreah. The mixture of coal and water is then lifted over a vertical height of 180 meters through a 200 mm vertical pipeline, and finally over a horizontal distance of 130 m to the washery, where the transporting water is recovered and returned to the main pump. The installation is designed to handle 50 tons/ hour of solids in a flow of 230 m^3/ h, but peaks of 60 t/ h have been maintained for long periods.

This pipeline has been plugged three times, but operations were resumed without difficulty after draining through the lower end of the vertical pipe. Water hammer problems have been satisfactorily solved with a Neyrpic nitrogen "pulsation absorber".

Size degradation of the coal does not seem to be much worse through the pipeline than it would be through conventional means of transportation. Typically, the proportion of minus 0.5 mm may be increased from 20% in the shaft bottom surge bins to about 24% at the end of the pipeline.

The lock hopper feeder pumps have a total installed power of 26.5 KW, but they have been generously designed (the high pressure pump is a Marep 20 KW). The optimum solids content of the pipeline flow seems to be 350 grams/ litre instead of the 190 g/ l usually sustained up to now.

It is estimated that a 100 t/ h pipeline would cost between 1.2 million NF and 2 million NF for depths between 200 m and 1000m. For a 200 t/ h pipeline these costs would become between 1.8 and 3 million NF. In the case of a depth of 1000 m, the lock hopper feeders would operate at 120 kg/ cm^2.

Publications

The French National Collieries have published some valuable reports on the transportation of solids by pipelines, the most notable of which are the following:

(1) Coeuillet, R., and Veillet, R. "Le transport hydraulique du charbon et des terres dans la mine". Revue de l'Industrie Minerale, No. Special IF, June 1956, Paper 21F, p. 425-58.

(2) Coeuillet, F. "Transport des solides en conduites, dans les houilleres". Technique Moderne, June 1960, p. 312-8.

(3) Lesage, M., and Bertard, C. "La remontee hydraulique du charbon au puits Devillaine des Houilleres du Bassin de la Loire". CERCHAR publication No. 1177, July 1961, E 491, 12 pp.

CONCLUSION

It seems that up to 1962, the Neyrpic-Sogreah organization may have spent about 500 million old Francs in the field of transportation of solids by water pipelines. The U.S. dollar is now worth about 5 NF, or 500 old Francs. However it must be noted that these expenditures were made over a period of years (since 1947) when the Franc has been devalued several times, so that the total expenses would be much higher than one million dollars. With due consideration of the lower wages in France and the many overhead expenses, that may have been charged to other sections of the Neyrpic-Sogreah group, the total investment is likely to easily exceed the equivalent of two million dollars. The present annual program of expenditures appears to be of the order of one million NF. The value of the solids pipeline research installations of Neyrpic-Sogreah is estimated at approximately two million NF. In addition, the considerable facilities and experience of the large Neyrpic hydraulics engineering and manufacturing groups are available to the solids pipeline research section, which has a very wide knowledge on this method of transportation for a variety of sizes and materials, including capsules, as shown above in the 44 projects in many countries. These most impressive testing facilities and

experience could be available to the Canadian industry through the Lasalle Hydraulic Laboratories of Montreal, a company associated with the Neyrpic-Sogreah group. It seems that feasibility studies on a specific project of solids pipelining would cost about 3 to 4 thousand dollars. These studies would give estimates with a precision of 10 to 30%. For more accurate feasibility studies with a 10% precision, the cost might be 10 to 20 thousand dollars. A few tons of the material to be transported would be required for the tests. Engineering responsibility for the construction of a solids pipeline would cost 12 to 14% of the total costs.

It has been stated by R.C. Worster, a prominent British Hydromechanics Research Association research worker in the field of solids pipelining, that "the information (provided by the Neyrpic-Sogreah investigations of Durand, Condolios, et al.) probably covers a wider range than all the other tests put together". (Proceedings of a Colloquium on the Hydraulic Transport of Coal, NCB, London, Nov. 5th, 1952, p. 14). The high value and wide experience of the Neyrpic group in solids pipelining has again been acknowledged by other research engineers in recent years. It seems that they could be made available for many Canadian projects of solids pipelining at much lower costs than those required for the building and operation of a new research station, as now contemplated in Western Canada.

RPC/ ph